4. PRODUCTION, IMPORT, USE, AND DISPOSAL

4.1 PRODUCTION

The lead industry consists of mine production, where lead ore (which occurs naturally mainly in the form of galena, lead sulfide) is crushed ground, conditioned, and concentrated (most commonly by flotation); primary metal production, where lead ore concentrate is treated through sintering, smelting, drossing, and refining to 99.99% purity; and secondary metal production, where scrap lead, primarily in the form of spent lead-acid batteries, product wastes, refinery drosses, and residues, is recycled (IARC 1980; Larrabee 1998; Woodbury 1985a). Mine production (ores and concentrates) is the feedstock used for primary production, and scrap metal is the feedstock used for secondary production. Almost all lead-producing mines in the United States are underground operations. Lead obtained as a by-product from open-pit copper mines is the only source of aboveground lead. Battery scrap is converted to impure lead or lead alloys by pyrometallurgical processes employing blast, electric arc, reverberatory, and/or rotary furnaces (Howe 1981; Larrabee 1998).

In 1996, the U.S. domestic lead industry was comprised of 17 mines located primarily in Alaska, Colorado, Idaho, Missouri, and Montana; two primary smelter-refineries in Missouri; a primary smelter in Montana; and 25 secondary (recycling) producers operating 31 plants. Of the lead recycled in 1996, 99% was produced by 10 companies operating 17 plants in Alabama, California, Florida, Georgia, Indiana, Louisiana, Minnesota, Missouri, New York, Pennsylvania, Tennessee, and Texas. Lead is also sold by the Defense National Stockpile Center (DNSC) as a result of legislation passed in 1992 authorizing the disposal of the entire 545,000 metric tons in the stockpile over several years. The law, however, requires the task to be completed without undue disruption of commercial lead markets (Larrabee 1997; Smith 1998).

In 1996, mines in Missouri and Alaska accounted for 93% of total U.S. lead mine production. Domestic lead mine production decreased in 1992 and 1993 as a result of low lead, gold, and silver metal prices, but increased the following three years when several mines either expanded or reopened due to increased metal prices. Domestic lead mine production reached 436,000 metric tons in 1996 and an estimated 450,000 metric tons in 1997, which was still less than the 484,000 metric tons produced in 1990 (Larrabee 1997; Smith 1998).

Domestic lead metal production rose at an annual rate of 1.3% between 1990 and 1996, going from 1.33 million metric tons to a record high of 1.43 million metric tons. Primary lead production declined at an annual average rate of 3.2% during this time period, dropping from 404,000 metric tons in 1990 to 326,000 metric tons in 1996. This decline was a result of cutbacks in production in 1991 and 1992 in response to low lead prices and of the closure of the primary lead refinery in Nebraska in 1996 (Larrabee 1997; Smith 1998). Primary lead production increased to 343,000 metric tons in 1997 (Smith 1998). Secondary lead production, however, rose at an average annual rate of 3.2%, climbing from 922,000 metric tons in 1990 to 1.1 million metric tons in 1996 and 1997 as the closure of 5 small secondary refineries was more than offset by the opening of a new secondary refinery and an increase of capacity at a number of other secondary facilities. As a result, secondary lead's share of total lead metal production rose from 69.5% in 1990 to 77.1% in 1996. In addition, between 1993 and 1996, the amount of lead in DNSC's inventory declined from 545,000 metric tons to 388,500 metric tons, and the disposal of about 54,000 metric tons has been authorized for each of fiscal years 1997 and 1998 by the respective Annual Materials Plans (Larrabee 1997; Smith 1998).

Table 4-1 lists the number of facilities in each state that have lead on site, the intended use, and the range of maximum amounts of lead that are stored on site. There are currently 1,476 facilities that produce or process lead or that have lead in some form on site in the United States. The data listed in Table 4-1 are derived from the Toxics Release Inventory (TRI96 1998). Only certain types of facilities were required to report. Therefore, this is not an exhaustive list. Table 4-2 shows the U.S. production volumes for lead during the years 1990 through 1997.

4.2 IMPORT/EXPORT

Imports of lead metal, which accounted for 17.5% of U.S. domestic consumption in 1996, rose from 90,900 metric tons in 1990 to 268,000 metric tons in 1996 and dropped slightly to an estimated 265,000 metric tons in 1997. In 1997, almost all imports came from Canada, Mexico, and Peru. Imports of lead waste and scrap, primarily from scrap lead-acid batteries, increased from 8,500 metric tons in 1990 to 14,800 metric tons in 1996, while the lead content of scrap lead-acid battery imports decreased from 6,800 metric tons in 1990 to an estimated 4,600 metric tons in 1996. Lead is also imported in the form of lead-acid batteries and other lead-containing products (Smith 1998; Larrabee 1998).

Table 4-1. Facilities That Manufacture or Process Lead

STATE [a]	NUMBER OF FACILITIES	RANGE OF MAXIMUM AMOUNTS ON SITE IN POUNDS [b]	ACTIVITIES AND USES [c]
AL	38	100 - 99,999,999	1 ,2 ,4 ,5 ,8 ,9 ,10 ,13
AR	28	0 - 9,999,999	1 ,4 ,5 ,8 ,9 ,12 ,13
AZ	15	1,000 - 1E12	1 ,2 ,3 ,4 ,5 ,6 ,8 ,9 ,10 ,12 ,13
CA	77	100 - 49,999,999	1 ,2 ,3 ,4 ,5 ,6 ,7 ,8 ,9 ,11 ,12 ,13
CO	8	1,000 - 999,999	2 ,3 ,7 ,9 ,12 ,13
CT	28	0 - 49,999,999	1 ,2 ,3 ,4 ,7 ,8 ,9 ,10 ,11 ,12
DE	4	1,000 - 9,999,999	12 ,13
FL	12	1,000 - 9,999,999	1 ,4 ,7 ,8 ,9 ,11 ,12
GA	40	100 - 9,999,999	1 ,2 ,3 ,5 ,8 ,9 ,10 ,12 ,13
IA	15	100 - 49,999,999	1 ,2 ,3 ,4 ,5 ,6 ,9 ,10
ID	3	10,000 - 999,999	9
IL	100	0 - 49,999,999	1 ,2 ,3 ,4 ,8 ,9 ,10 ,12 ,13
IN	93	100 - 49,999,999	1 ,2 ,3 ,4 ,5 ,7 ,8 ,9 ,10 ,12 ,13
KS	25	0 - 9,999,999	1 ,2 ,3 ,8 ,9 ,12 ,13
KY	35	100 - 9,999,999	1 ,2 ,3,4 ,5 ,7 ,9 ,10 ,11
LA	14	0 - 49,999,999	1 ,3, 5 ,7 ,9 ,11 ,12
MA	35	1,000 - 9,999,999	8 ,9 ,12
MD	7	1,000 - 999,999	9 ,12 ,13
ME	1	1,000 - 9,999	2 ,3 ,9
MI	59	0 - 999,999	2 ,3 ,4 ,5 ,8 ,9 ,10 ,11 ,12 ,13
MN	18	1,000 - 9,999,999	1 ,4 ,9 ,13
MO	41	0 - 499,999,999	1 ,3 ,4 ,5 ,7 ,8 ,9 ,10 ,11 ,12
MS	32	1,000 - 9,999,999	2 ,3 ,8 ,9 ,12 ,13
MT	2	10,000 - 499,999,999	1 ,2 ,3 ,4 ,7
NC	35	0 - 49,999,999	1 ,5 ,8 ,9 ,10 ,12 ,13
ND	1	100,000 - 999,999	11
NE	16	100 - 99,999,999	2 ,5 ,8 ,9 ,12
NH	11	100 - 99,999	9
NJ	46	100 - 9,999,999	1 ,2 ,3 ,4 ,7 ,8 ,9 ,12 ,13
NM	3	10,000 - 999,999	13
NV	3	10,000 - 999,999	2 ,3 ,4 ,9 ,10
NY	58	0 - 49,999,999	1 ,2 ,3 ,4 ,5 ,8 ,9 ,10 ,11 ,12 ,13
OH	154	0 - 49,999,999	1 ,2 ,3 ,4 ,5 ,6 ,7 ,8 ,9 ,10 ,11 ,12 ,13
OK	16	100 - 49,999,999	1 ,5 ,9 ,10 ,11 ,12
OR	9	1,000 - 9,999,999	9 ,11
PA	94	100 - 49,999,999	1 ,2 ,3 ,5 ,7 ,8 ,9 ,10 ,12 ,13
PR	4	100 - 99,999	2 ,3 ,9 ,12
RI	15	100 - 999,999	2 ,3 ,4 ,8 ,9 ,13
SC	30	0 - 9,999,999	1 ,5 ,6 ,7 ,8 ,9 ,10 ,12 ,13
SD	2	1,000 - 9,999	9
TN	47	100 - 49,999,999	1 ,2 ,3 ,4 ,5 ,7 ,9 ,10 ,11 ,12 ,13
TX	92	0 - 9,999,999	1 ,2 ,3 ,4 ,5 ,6 ,8 ,9 ,10 ,11 ,12 ,13
UT	13	1,000 - 9,999,999	1 ,3 ,4 ,5 ,8 ,9 ,11 ,12 ,13
VA	24	0 - 999,999	1 ,2 ,3 ,5 ,6 ,8 ,9 ,12 ,13
VT	5	1,000 - 999,999	9 ,12
WA	13	100 - 9,999,999	1 ,2 ,3 ,4 ,6 ,8 ,9 ,10 ,12
WI	44	0 - 999,999	1, 2 ,3 ,4 ,5 ,7 ,8 ,9 ,10 ,12 ,13
WV	9	1,000 - 999,999	1 ,2 ,3 ,5 ,8 ,9 ,12
WY	2	1,000 - 99,999	1 ,4 ,10

Source: TRI96 1998

[a] Post office state abbreviations used
[b] Range represents maximum amounts on site reported by facilities in each state
[c] Activities/Uses:

1. Produce
2. Import
3. Onsite use/processing
4. Sale/Distribution
6. Impurity
7. Reactant
8. Formulation Component
9. Article Component
11. Chemical Processing Aid
12. Manufacturing Aid
13. Ancillary/Other Uses

Table 4-2. U.S. Lead Production January 1990 through 1997

	Production volumes in metric tons							
Type of lead	1990	1991	1992	1993	1994	1995	1996	1997
Mined (recovered): domestic ores, recoverable lead content	484,000	466,000	397,000	355,000	363,000	386,000	426,000	448,000
Primary (refined): domestic/foreign ores and base bullion	404,000	345,900	304,800	334,900	351,400	374,000	326,000	343,000
Secondary (refined): lead content	922,000	885,000	916,000	893,000	931,000	1,020,000	1,070,000	1,110,000

Source: DOI/USGS 1997a; Smith 1995, 1998

Exports of lead metal increased from 55,500 metric tons in 1990 to 94,400 metric tons in 1991, then fell to 44,000 metric tons in 1996 and 37,400 metric tons in 1997. In 1997, the U.S. exported lead metal primarily to South Korea, Canada, United Kingdom, Malaysia, Belgium, and Taiwan. Lead waste and scrap exports, which amounted to 71,900 metric tons in 1990, rose to 104,300 metric tons in 1995, dropped to 85,300 metric tons in 1996, and rose to 88,400 metric tons in 1997. The lead content of exported scrap lead-acid batteries went from 4,800 metric tons in 1990 to 1,400 metric tons in 1995. No later export tonnage figures for scrap lead-acid batteries are available for 1996 because the data were collected by dollar value only. Most exports are in the form of lead-acid batteries or products containing either lead-acid batteries or other applications of lead (Larrabee 1998; Smith 1998).

4.3 USE

Lead may be used in the form of metal, either pure or alloyed with other metals, or as chemical compounds. The commercial importance of lead is based on its ease of casting, high density, low melting point, low strength, ease of fabrication, acid resistance, electrochemical reaction with sulfuric acid, and chemical stability in air, water, and soil (Howe 1981; Shea 1996). At least half of all lead consumed worldwide goes into producing lead-acid batteries used in automotive and various industrial applications. Certain dispersive or readily bio-available uses, such as lead in gasoline, as a solder in piping for drinking water and food cans, and in house paints, have been or are being phased out due to environmental and health concerns (Larrabee 1998).

Prior to the EPA beginning to regulate the lead content in gasoline during the early 1970s, approximately 250,000 tons of organic lead (e.g., tetraethyl lead) were added to gasoline on an annual basis in the United States (Giddings 1973). These lead-based “anti-knock” additives increased the octane rating of the gasoline and as a result increased engine efficiency (Giddings 1973). In 1971, the average lead content for a gallon of gasoline purchased in the United States was 2.2 grams per gallon (Giddings 1973). After determining that lead additives would impair the performance of emission control systems installed on motor vehicles, and that lead particle emission from motor vehicles presented a significant health risk to urban populations, in 1973 EPA initiated a phase-down program designed to minimize the amount of lead in gasoline over time. By 1988, the phase-down program had reduced the total lead usage in gasoline to less than 1% of the amount of lead used in the peak year of 1970 (EPA 1996f). In 1990, a Congressional amendment to the Clean Air Act (CAA) banned the use of gasoline containing lead or lead additives as fuel in motor vehicles. On February 2, 1996, the EPA incorporated the statutory ban in a direct final rule which defined unleaded gasoline as gasoline containing trace amounts of lead up to 0.05 gram per gallon (EPA 1996f). The definition still allowed trace amounts of lead but expressly prohibited the use of any lead additive in the production of unleaded gasoline. The term “lead additive” was defined to include pure lead as well as lead compounds (EPA 1996f). Although the regulatory action of Congress banned the use of leaded gasoline as fuel in motor vehicles, it did not restrict other potential uses of gasoline containing lead or lead additives (EPA 1996f). Gasoline produced with lead additives continues to be made and marketed for use as fuels in aircraft, race cars, and non-road engines such as farm equipment engines and marine engines, to the extent allowed by law (EPA 1996f), but tetraethyl lead has not been produced in the United States since March 1991, and all gasoline sold for motor vehicle use since January 1, 1996, has been unleaded (EPA 1997).

In 1996, lead was consumed by 186 facilities in the United States. The most significant use of lead metal is for lead-acid storage batteries used in automotive and industrial applications (Larrabee 1998). Other current commercial uses of lead metal include producing ammunition in the form of shot and bullets; bearing metals for machinery, electrical and electronic equipment, motor vehicles and other transportation equipment; brass and bronze billets and ingots; cable coverings in the power and communication industries; pipes, traps, and other extruded products for building construction, storage tanks, process vessels. Lead-based metal products also include sheet lead for building construction, storage tanks, process vessels, and medical radiations shielding; solder for building construction, motor vehicles, equipment, metal cans and shipping containers, and electronic components and accessories; storage batteries, including storage battery grids and posts. Lead oxides are used in paint, glass, and ceramic products (Smith 1998).

Reported consumption of lead increased at an average annual rate of 3.3% between 1990 and 1996. Consumption patterns have long been shifting to a market dominated by one major end use: the lead-acid battery. Increasing lead-acid battery demand has more than made up for all end-uses that have either significantly declined or been legislated out of existence for environmental and health reasons. The lead-acid battery share of total domestic lead consumption increased from 79.7% in 1990 to 87.6% in 1996 and grew at an average annual rate of 5.2% over the period. At the same time, non-battery uses of lead declined at an average annual rate of 4.5%. Except for a sharp increase in 1995, lead used in ammunition (the largest non-battery end-use) remained fairly constant during this period. Other uses, such as cable covering, caulking, and solder, have declined significantly while tetraethyl lead additives for gasoline, which once accounted for 20% of domestic consumption, has been phased out except for the exceptions noted above (Larrabee 1998; Smith 1998).

The lead-acid battery is the driving force behind the lead industry both globally and domestically. This sector consists of two main markets: starting, lighting, and ignition (SLI) batteries, which presently account for 83% of the market; and industrial batteries, which currently account for 17% of the market. SLI batteries are used in passenger cars and light trucks, heavy commercial vehicles, motorcycles, special tractors, marine equipment, aircraft, and military vehicles. Between 1990 and 1996, SLI battery production increased at an average annual rate of 4.3%, rising from 79.6 million units to 100 million units. An estimated 1.1 million metric tons of lead was consumed in SLI batteries (Battery Council International 1998; Larrabee 1998; Smith 1998).

The industrial battery market is divided into two sectors: motive power and stationary power. Motive power includes batteries for industrial trucks, mining vehicles, and railroad cars and presently accounts for 39% of the industrial battery market. Stationary power includes batteries for telecommunications, uninterruptable power supply (UPS) units, and control and switchgear equipment and presently accounts for the remaining 61% of the industrial battery market. The industrial battery market jumped 19% in 1995 and registered an average annual growth rate of 11.2% between 1990 and 1996, with the strongest rise in the stationary sector, which grew at an average annual rate of 20.5% during this period. The rapid rise in the stationary power sector was due to strong demand for communications and UPS batteries. The pace of market activity for these batteries is expected to accelerate further due to de-regulation of the telecommunications industry (Battery Council International 1998; Larrabee 1998).

The domestic use pattern for lead in 1990 was as follows: lead-acid storage batteries, used for motor vehicles, motive power, and emergency back-up power, accounted for 80% of total lead consumption; ammunition, bearing metals, brass and bronze, cable covering, extruded products, sheet lead, and solder, represented 12.4%; the remaining 7.6% was used for ceramics, type metal, ballast or weights, tubes or containers, oxides, and gasoline additives (USDOC 1992).

The substitution of plastics could continue to reduce the use of lead in building construction, electrical cable covering, and cans and containers. In addition to plastics, aluminum, tin, and iron continue to compete with lead in other uses such as packaging and coatings (DOI/USGS 1997b). In the United States, tin has replaced lead as solder used in new or replacement potable water systems (DOI/USGS 1997b).

Despite these market losses, new uses have been or are being developed that hopefully do not present the environmental and health problems associated with some of the old uses of lead. The following list shows some recent and possible new critical uses of lead:

- Lead's advantages in providing protection against radiation exposure have facilitated advances in computers and televisions (which emit gamma rays and X-rays while in operation), medical procedures such as magnetic imaging for diagnostics and many kinds of radiation therapy, and nuclear technology used in a variety of commercial and military applications.
- Lead alloy solder is critical to the transistors, relays, and other components in the printed circuit boards used in all computers and advanced electronic equipment.
- Piezoelectric ceramics, which depend on lead compounds, are used to produce transducers and sensors which make possible ultrasound technologies used in wide-ranging medical and commercial applications, guidance and sensing systems used in defense and commerce, and in addition, new "smart materials" research projects.
- High-purity lead oxide is used to make precision glasses needed for lasers, low-dose X-ray machines, fiber optic probes, medical camera systems, and low-light military equipment such as night vision scopes and goggles.
- A new cogeneration technology is now being developed outside the United States operates by recirculating molten lead throughout a sealed system. This concept could result in highly efficient energy generation and reduced depletion of fossil reserves.
- Lead-based, high-temperature superconductors are being studied in several research projects. Their superior performance characteristics are expected to facilitate development of new hyper-fast computers, as well as more sensitive medical diagnostic equipment, more efficient energy delivery systems, and new forms of high-speed surface transportation.
- Lead continues to be used in pigments. For example, lead chromate and lead oxide are used in paints, and lead acetate is used in hair dyes.

4.4 DISPOSAL

Although certain uses of lead preclude recycling (e.g., use as a gasoline additive), lead has a higher recycling rate than any other metal (Larrabee 1998). An estimated 90-95% of the lead consumed in the United States is considered to be recyclable. In the United States, 77.1% of the lead requirements were satisfied by recycled lead products (mostly lead-acid batteries) in 1996. This compares to 69.5% in 1990 and 55.2% in 1980 (Larrabee 1997, 1998).

Disposal of wastes containing lead or lead compounds is controlled by a number of federal regulations (see Chapter 7). Lead is listed as a toxic substance under Section 313 of the Emergency Planning and Community Right to Know Act (EPCRA) under Title III of the Superfund Amendments and Reauthorization Act (SARA) (EPA 1988). Lead-containing waste products include storage batteries, ammunition waste, ordnance, sheet lead, solder, pipes, traps, and other metal products; solid waste and tailings from lead mining; items covered with lead-based paint; and solid wastes created by mineral ore processing, iron and steel production, copper and zinc smelting, and the production and use of various lead-containing products (DOI 1987a; EPA 1982a).

Presently, 37 states have enacted legislation to encourage recycling of lead-acid batteries. These states have adopted laws that prohibit disposal of lead-acid batteries in municipal solid waste streams and require all levels of the collection chain to accept spent lead-acid batteries. Four other states ban only the land-filling and incineration of lead-acid batteries. Battery recycling rates are determined by comparing the amount of lead recycled from batteries with the quantity available for recycling in a given year. Recycling facilities can usually provide data on the amount of lead produced from scrapped batteries; however, the amount of lead available for recycling is largely influenced by the battery's useful life span. Therefore, to determine the amount of lead available from batteries for a given year requires historical data on battery production and average lead content, as well as import and export data on new batteries, vehicles containing batteries, scrap lead and scrapped batteries (Larrabee 1998). The 1995 annual study released by the Battery Council International reported an average annual lead-acid battery recycling rate of 94.9% between 1990 and 1995 (Battery Council International 1998).